# Cost allocation model for a synergetic cooperation in the rollout of telecom and utility networks

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*Abstract*— **Fiber to the Home delivers the most future proof solution for fixed telecom access networks. This technology requires the installation of optical fiber in the last mile. However, the penetration of FTTH services is Europe is lagging, with only marginal uptake in most countries. One of the main causes of this low penetration is the higher initial installation cost for a fiber access network. Regulation typically enforces a fully buried installation, which results in an investment cost around €750 per house passed. Driving down this cost is a main focus of research. A joint rollout with other utility infrastructure network operators can decrease the initial rollout cost for all utility and telecom infrastructure actors involved in the process. This paper presents an innovative approach to cost sharing in the rollout of access networks. The cost model presented allows for cost savings up to 17% per home passed for the telecom operator.**

***Keywords: Cost allocation, Fiber to the Home, Techno-Economics***

## I. INTRODUCTION

The introduction of fiber in telecom access networks will be required in the upcoming years to cope with increasing network demands. Fiber to the Home (FTTH) networks can offer higher bandwidth and thus new services for customers compared to current access networks. As this solution requires the installation of optical fiber in the last mile, connecting the central office with the customers, this is often a postponed investment, certainly if a fully buried solution is obligatory. The initial installation of a FTTH network requires a high upfront investment. For underground networks, digging costs represent 60 to 70% of the initial investment [1]. Costs for deploying a FTTH network have been estimated between 500 and 1500 euro per home passed. This high upfront investment is one of the main reasons the rollout of FTTH networks has not taken off yet in Europe.

When comparing the penetration rates of FTTH in the world, Europe is seriously lagging compared to Asia and North America. Compared with the penetration rate of fiber to the building/home in Asia Pacific (45.08%), South-East Asia (18.89%) and North America (6.66%), Western Europe is behind with 2.23% [2].

In recent years, we notice a shift in perception where telecom networks are regarded as just another utility network, like electricity, gas or water networks, due to a lot of similarities in infrastructure and operations. The unbundling of the electricity market, with structural separation of infrastructure and operations in different companies, can be seen as an example for future telecom networks [3]. One company rolls out the access infrastructure and sells network access to suppliers offering services over this network. Distribution grid operators offer the network infrastructure and sell access to this network to energy suppliers. These suppliers sell the energy to the end consumer.

In addition to this regulatory trend, other factors allow for the comparison of telecom networks with utility networks. Rolling out these networks results in large infrastructure works, e.g. opening roads, resulting in nuisance for inhabitants. Both utility and telecom networks are usually deployed in the same place in the roads. If these networks are not deployed in the same sector of the road, the nuisance reduction and cost gains from joint rollout are strongly reduced. Recent policy aims at reducing nuisance for inhabitants by stimulating cooperation between the different infrastructure owners. Penalty systems are foreseen to encourage this, but rules could be by-passed (e.g. due to maintenance works, too low penalty costs in which it still stays profitable when not cooperating, etc.). Combining the rollout of different utility networks would thus drive down the upfront investment by cost sharing between all actors involved in the deployment process.

This paper describes a new cost allocation model for the rollout and operation of infrastructure networks and compares it with the cost of independent rollout and operation. We will show how cooperation in the rollout phase drives down the initial investment cost and can as such be a driver for a faster FTTH rollout. In Section II, first the typical characteristics of the networks are described. Next, more detail on the current trench model is given. Section III discusses the cost model and the paper continues with results in Section IV. We will show how the joint rollout of infrastructure networks can reduce the initial investment cost for all actors. Section V concludes and gives topics for future work.

We will only focus in this paper on the CapEx (capital expenses), thus the installation cost of the different networks. The OpEx (operational expenses) such as maintenance and repair are not included in our cost model.

## II. Network infrastructures

In this section, we will provide an overview of the different utility infrastructures currently deployed underground. Next to the standard utility networks, like gas, electricity, water and sewage networks, telecom infrastructure is discussed.

### *A. Utility access network synergies*

Figure 1 shows an overview of the different network parts (access network up to the building, within the building, within the home e.g. apartment) when looking at utility (and telecom) access network infrastructures [4]. On the horizontal level we have foreseen four network lifecycle phases: deployment of the network, provisioning connection (pre-registration or later on) to the customer and network operations. Upon this model we mapped the actors involved for each part.

We focus on the network parts where the different utility (and thus also telecom) access infrastructure network owners could cooperate. This is the lowest part of the figure, indicated in light grey) namely the role of physical infrastructure access providers (PIP), deploying their networks up to the demarcation point in the building (thus also provisioning pre-registration and later-on connection) and delivering network access and operations (maintenance, repair, etc.). In our model, we focus on the left part of the PIP (dark gray area), thus the actual deployment which includes right of way, trenching, ducts, cables and flexibility points. The customer connection and operations are not included in this study.

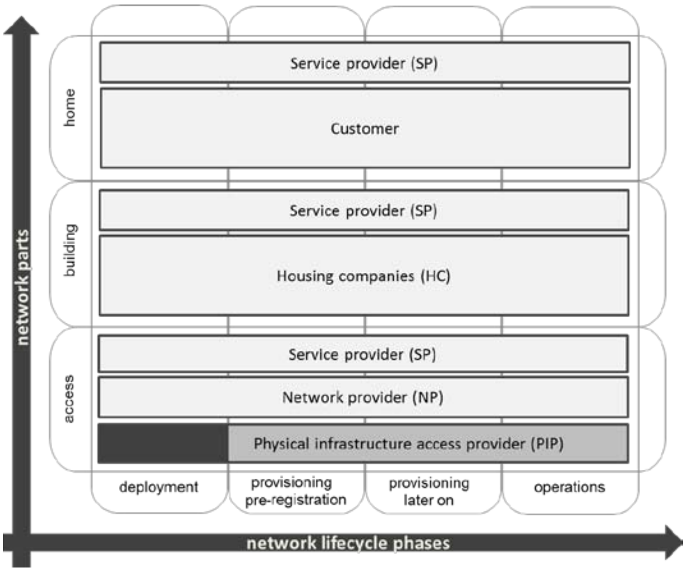


**Figure 1: Overview of potential utility network rollout synergies**

Telecom networks cover a broad range of possible infrastructures like HFC (hybrid fiber coax) and DSL networks (based on fiber – copper solutions) and fiber networks. The incumbent's copper network is a fully buried network, laying currently at a depth of minimum 60 cm. This is also the case for the HFC network of the cable operators, and other telecom infrastructure (such as dark fiber, business fiber connections). At regular distance, flexibility points (man holes and hand holes, but also street cabinets) are required. Few requirements are in place for these types of networks.

An energy network comprises both the electricity and gas networks. Electricity networks are quiet flexible (cf. telecom). For gas access networks, a more rigid infrastructure is used for increased safety measures. A safety distance to other infrastructure is required. This network can also be found deeper underground than electricity. In Belgium, both networks can be found underneath the footpath, close to the buildings. No other infrastructure is allowed to be placed above and beneath gas networks.

Drinking water also makes use of a rigid network infrastructure, and can be found at a depth of 110 cm underneath the footpath. No other infrastructure is allowed to be placed above and beneath this network.

Sewage networks can be found in the middle of the road. For new rollouts a separated network (for rain and sewers) is obligatory.

### *B. Standard trench*

When looking at a cross-section of a typical road in Belgium, we see that the networks described in the previous sections, except for the sewage system, are located in the same area on both sides of the street. The sewage system is typically located in the middle of the street and would require the whole street to be opened if it needs maintenance. Since the digging would already be necessary for the sewage system, other infrastructure networks could benefit from this work to rollout their infrastructure at a reduced cost, since no extra digging would be required. More in general, when a government decides to conduct large road works, it is designated for infrastructure companies to rollout their networks during these road works. The digging cost for road works is carried by the federal or regional government, for the other infrastructures by the network owner.

A lot of regulation has been put in place for the rollout of underground network infrastructure. The proximity of different cables next to each other requires safety precautions. Nuisance reduction is an important issue in infrastructure works, and both federal and local governments strive for a more coordinated approach in road works.

This resulted in the description of a standard trench. When infrastructure needs to be installed, several guidelines have been put in place, describing the position of each cable or duct in the road [5]. For each type of infrastructure, different parameters describe the requirements of the trench. These include distance to other cables or ducts, trench width and minimal coverage of the cable. Based on these three parameters, the total depth and width of the trench can be calculated. An extra requirement for gas and drinking water ducts is that no other cables may be placed above or under this duct. Table 1 gives an overview of the different parameters for each type of infrastructure.

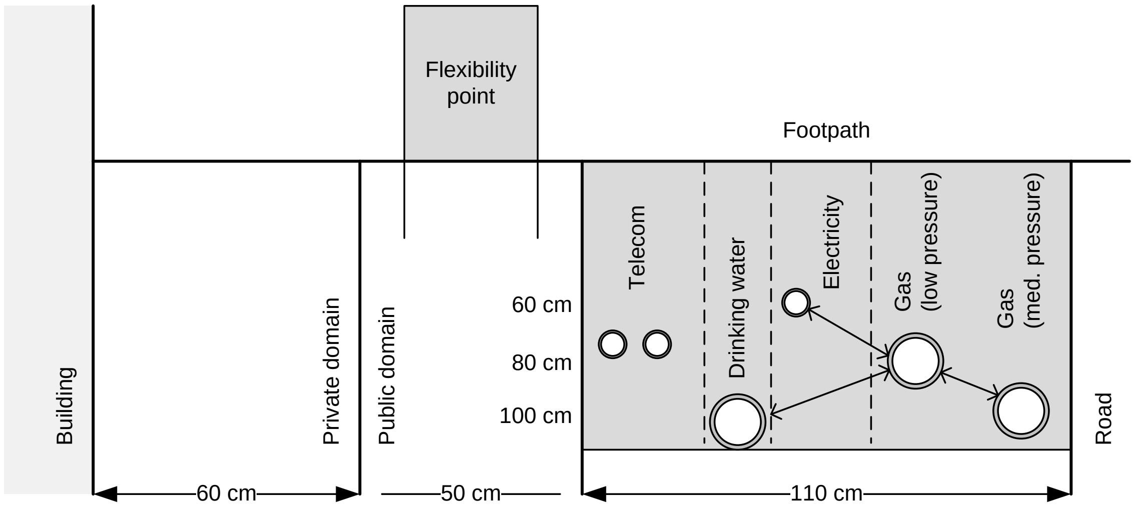


**Figure 2: Cross-section of a typical road**

**Table 1: Proposed standard trench parameters**

| Infrastructure type | Depth (m) | Distance to wall of trench (m) | Distance to other cables (m) |
|---|---|---|---|
| Electricity | 0.6 | 0.05 | 0.06 |
| Gas – low pressure | 0.8 | 0.1 | 0.2 |
| Gas – medium pressure | 1 | 0.1 | 0.2 |
| Telecom | 0.75 | 0.05 | 0 |
| Drinking water | 1.10 | 0.1 | 0.2 |

Figure 2 shows the cross-section (left side of the road) of a standard trench. To prevent damage to the buildings, a minimum distance of 1.10m should be taken into account between the buildings and the cables and ducts (for Greenfield situations). For the same reason, the trench is not allowed to be deeper than 1.20m. A width of 110 cm is reserved for infrastructure.

Based on this standard trench, we developed a cost model for the rollout of access infrastructure. This model is described in the next section. Given the limited amount of available cost data on water and sewage networks, we will limit ourselves to the cooperation between a telecom network provider and an energy network provider. The same model can be extended to include the other networks as well.

## III. Cost Allocation model

Before going into detail on the different costs taken into account in the cost allocation model, some theoretical background is provided on cost categories and the different allocation schemes.

### *A. Cost categories*

We make a distinction between three large cost categories. In cost accounting theory, these categories are defined as direct costs, shared costs and common costs [6]. Direct costs are specific for a certain actor and can be directly attributed to this actor. When infrastructure rollout is done jointly, this type of costs is borne by one actor and not divided between the other infrastructure providers. No specific cost allocation key is necessary to assign these costs to the different actors. Typical examples of direct costs are the material cost of cables, ducts and flexibility points and the installation of this equipment.

Shared or joint costs can be divided between the different actors involved in the rollout based on a cost driver (e.g. time, equipment used, etc). In infrastructure rollout projects, a typical example is the digging of the shared trench. Using a fair allocation scheme, this cost can then be allocated to each actor e.g. making use of TDABC (time-driven activity based costing) [7].

The last cost category considered consists of common costs. Unlike the previous cost types, these cannot be attributed to a specific actor directly, based on a cost driver. Typically overhead costs, like administration and licensing costs are in this category. These costs are divided between all involved actors based upon own discussed rules.

### *B. Cost allocation methods*

In order to come to a fair comparison of the different rollout strategies, between an independent rollout of the network infrastructure and a jointly operated rollout, we use two different cost allocation methods.

The stand alone cost (SAC) is the first allocation method. SAC is used to calculate the cost for the network rollout as if there would be no cooperation between the infrastructure owners. All direct, shared and common costs can be directly allocated to one actor (Figure 3).

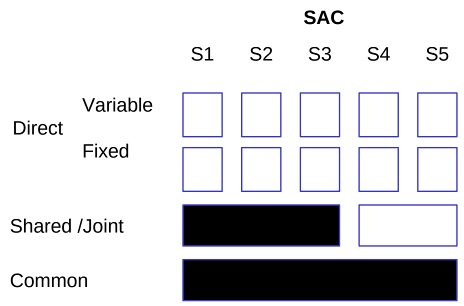


**Figure 3: Stand-alone cost principle**

In contrast with this method, we use the fully allocated cost (FAC) to calculate the rollout cost for each actor under cooperation. This allocation scheme divides the costs under the cooperating actors. Direct costs are directly contributed to each actor, the shared and common costs can be assigned to the respective actors based on a fair cost allocation key (Figure 4).

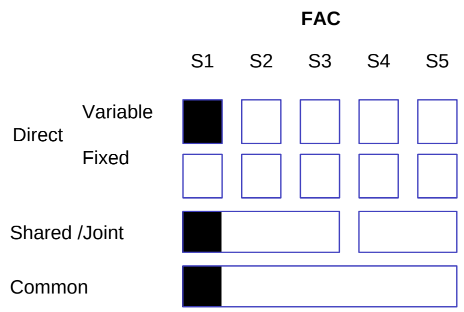


**Figure 4: Fully allocated cost principle**

### *C. Cost impacting factors*

Cooperation in the rollout phase should be interesting for all actors involved. The shared costs will offer the most possibilities for cost reduction. Since trenching contributes to on average 60 to 70% of the rollout costs [1], the costs related to this activity are discussed into more detail.

The total trenching cost can be divided in two separate parts, digging costs and installation costs. The total digging costs is driven by two different parameters. First, based on the actors involved in the cooperative rollout, the dimensions of the trench can be modeled. A stand-alone rollout will result in a smaller trench compared with a joint rollout, but the incremental cost of a joint rollout is spread out over more actors. In section II we indicated that several restrictions are imposed on the rollout of network infrastructures. Depending on the type of infrastructure present in the trench, the dimensions of the trench can be calculated.

Secondly, the type of paving is also an important parameter influencing the total digging cost. We distinguish between three types of paving, asphalt, loose pavement and bank. In case there is no paving present, the contractor can start digging directly. In the two other cases, loose pavement and asphalt, the pavement needs to be removed before the digging of the trench can start. While loose pavement can be reused after the works to restore the pavement, asphalt cannot. In the case of asphalt, a new foundation needs to be placed before the pavement can be restored.

From the dimensions of the trench and the pavement type, the total amount of work hours for digging can be derived. Work hours for digging are composed of the time necessary for opening the road, digging and filling the trench and closing the road.

Installation costs are the second important part of the total trenching cost. Installation costs consist of all costs made during the initial installation of the network. In our model, personnel costs are the most important installation cost. Next to these costs we also included costs for digging and transport equipment. The installation of the duct is an infrastructure specific cost, but cooperation can impact the total installation time. Efficiency losses can occur when cooperating in the rollout of the network.

When several ducts need to be installed in the trench, this cannot be done simultaneously. Imagine three persons installing their own cable in a trench of one meter. A factor representing the time loss caused by cooperation is inserted in the model. However, starting from a certain trench length, the time losses can be neglected due to sequenced coordination of work. Figure 5 shows the impact of cooperation on the total work time.

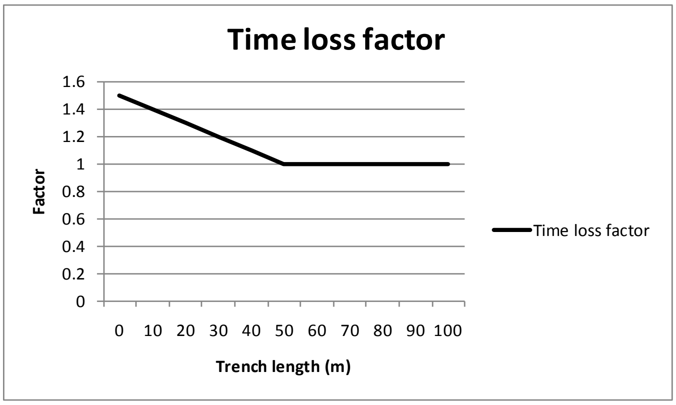


**Figure 5: Relation between trench length and efficiency losses**

As indicated in section III.B, direct costs are actor specific. In case of the installation of an access infrastructure for any type of access network, these costs comprise of the installation of flexibility points, cable and duct cost. An overview of these costs can be found in Table 2 [5]. Notice that the cost of making the physical connection with the customer premises is not included.

Common costs will not be taken into account in this model. These costs will raise the total investment each actor has to make, but the absolute rise in cost will be equal for each actor.

**Table 2: Installation and direct costs**

| Cost type | Cost |
|---|---|
| Personel cost (€/hour) | 36.75 |
| Truck (€/hour) | 15.75 |
| Digging machine (€/hour) | 17.85 |
| Electricity cable (€/m) | 3.22 |
| Fiber cable (€/m) | 3.00 |
| Gas duct (€/m) | 3.50 |

### *D. Cost allocation key*

In the previous paragraphs, we indicated some cost distribution methods. To allocate the costs fairly, a cost allocation key need to be decided on. We have shown how the presence of different infrastructures in the trench impacts the total volume of the trench. This digging volume in turn influences the total digging costs and working hours. Next to the trench volume, the pavement type also influences the trenching costs. As such, the trench volume and pavement type, reflected in the digging costs, are a fair basis for a cost allocation key for the trenching cost. This key is derived for each actor from the following formula (1).

$$\text{Cost allocation key}\, i = \frac{\text{Digging cost}\, i}{\sum_{i=1}^{n} \text{Digging cost}\, i} \quad (1)$$

With *Digging cost i* as the digging cost when the actor rolls out the network independently.

For the installation costs, a similar cost allocation key is made, now based on these installation costs. These consist of the personnel costs made during the installation of cables and ducts and the equipment costs. Digging equipment and heavy machinery is included in this cost.

## IV. IMPACT OF COOPERATION ON TRENCH VOLUME

The goal of this model is to show that cooperation in the rollout phase of a network offers great possibilities for cost reduction. Especially for FTTH networks, where this cost is still the greatest barrier inhibiting the introduction of these networks in Europe, even a small cost reduction could result in a faster rollout of these networks.

For buried networks, a joint rollout offers many opportunities for cost reduction. Sharing the trenching cost will already greatly decrease the total cost for each actor. In this section we will show how cooperation influences the total trench volume and thus the total initial investment. A description of three different scenarios will be given. In each scenario, a telecom operator rolling out fiber is present and we will show in the last two scenarios how the cooperation reduces the initial investment for this actor. The initial assumptions for all scenarios are the same. We work with a trench length of 100m in a Greenfield situation (one side of the road) and the cables are placed under loose pavement. After installation, the pavement needs to be fully restored. We assume that along this 100m, 20 premises are present. For all networks, the flexibility points have to be foreseen as well. This can be compared with the rollout of a new network in an urban area. For the different scenarios, we will start with a description of the investment costs when each actor decides to roll out the network separately. Next, the impact of cooperation in the rollout phase will be discussed.

### *A. Independent rollouts*

First we want to present the base case where all operators are rolling out their network separately. Figure 6 shows the cross-section of separate trenches for electricity, fiber and gas infrastructure networks. In case of an independent rollout, the fiber operator needs to dig a total of $24m^3$. Including the installation of flexibility points, this comes down to a total cost of €470 per home passed. Making the same calculations for the electricity network operator, we come to a cost of €461 per home passed. For the gas operator, this cost will be €479. This sums up to a total of €1,410 per home passed.

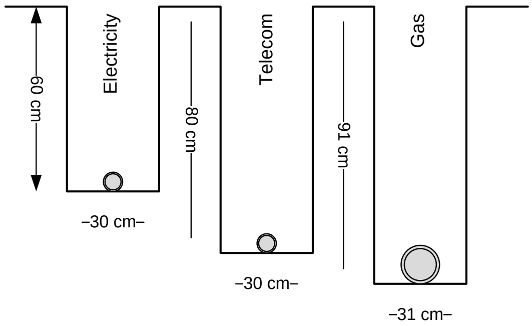


**Figure 6: Individual rollout (SAC)**

| | **Electricity** | **Fiber** | **Gas** |
|---|---|---|---|
| Digging cost | €82 | €91 | €96 |
| Installation cost | €113 | €114 | €115 |
| Equipment cost | €266 | €265 | €268 |
| **Total cost** | **€461** | **€470** | **€479** |

### *B. Joint electricity / fiber rollout*

Regulation allows placing an electricity cable on top of a fiber cable, taking into account a safety distance between the cables. This results in a total trench volume for both actors equal to the volume the fiber operator would need to dig if he would roll out the network alone.

The cost allocation key is derived from the cost when the operators would roll out the network independently. This means the road should be opened twice and each operator needs to dig his own trench. This results in important time losses during the installation phase. When we look at the results in Table 3, the following conclusions can be drawn. Under cooperation, the trenching cost can be reduced by almost 50% for each actor. The impact of cooperation on the total investment cost for the fiber operator is close to 17%. When considering that the trenching cost is between 60 and 70% of the total cost of a fiber network, this comes down to a cost reduction of over 8%. When taking into account the large investment necessary for fiber rollout, this is a considerable cost reduction.

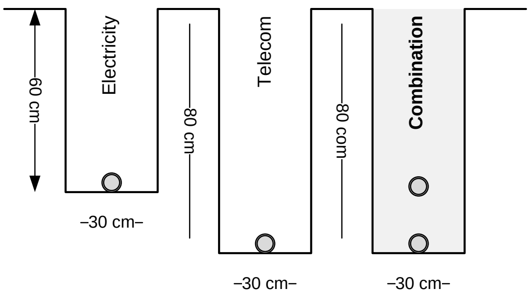


**Figure 7: Electricity / Fiber trench cross-section**

**Table 3: Cost results electricity/fiber rollout (FAC)**

| | Electricity | Fiber | Cooperation |
|---|---|---|---|
| Digging cost | €43 (-47%) | €48 (-50%) | €91 |
| Installation cost | €86 (-24%) | €87 (-24%) | €173 |
| Equipment cost | €266 | 265 | €531 |
| **Total cost** | **€395 (-14%)** | **€400 (-17%)** | **€795** |

*C. Joint electricity / fiber / gas rollout*

The impact on the trench layout of a joint rollout between three operators is shown in Figure 8. The presence of a gas network will raise the total volume of the necessary trench, but in this case the total costs can be shared between three operators. From Table 4 we can conclude that the total cost savings for fiber is slightly higher than in the previous scenario.

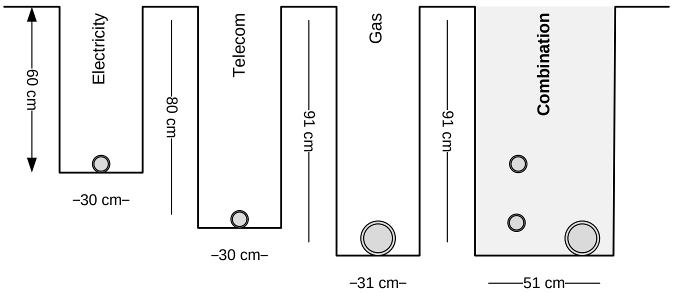


**Figure 8: Cross-section of trench with three operators**

These two scenarios have shown that the synergy gains from a joint rollout of a fiber network with a utility network offers considerable cost saving possibilities for all actors present in the network rollout. This last scenario is most probable in the case of Belgium where gas and electricity networks are owned by the same actor (multiple municipality structures).

**Table 4: Cost results electricity/ gas / fiber rollout (FAC)**

| | Electricity | Fiber | Gas | Cooperation |
|---|---|---|---|---|
| Digging cost | €38 (-54%) | €42 (-56%) | €45 (-50%) | €125 (-53%) |
| Installation cost | €89 (-21%) | €90 (-22%) | €92 (-19%) | €272 (-21%) |
| Equipment cost | €266 | 265 | 265 | €799 |
| **Total cost** | **€393 (-15%)** | **€397 (-17%)** | **€405 (-14%)** | **€1.196 (-15%)** |

*D. Impact of pavement type on cost reduction*

In the previous paragraph, we only considered scenarios where the cables and ducts were installed under loose pavement. However, as can be seen from Figure 9, the type of pavement has a considerable impact on the trenching costs. It is cheaper to open up loose pavement than an asphalt road. Since a lot of synergy is gained from the fact that the pavement only has to be opened up once, this clearly reflects in the possible cost savings for the fiber network operator. On the left side the stand alone cost for the fiber operator per house passed can be seen. Opening en closing asphalt is clearly more expensive than loose pavement (+43%) or bank (+119%). When considering the cooperation scenarios, the difference between the types of pavement stays but is reduced. When combining effort, about 40% can be saved for asphalt environments (e.g. urban cities), 35% for loose pavement and 22% for bank, comparing with the stand alone cost.

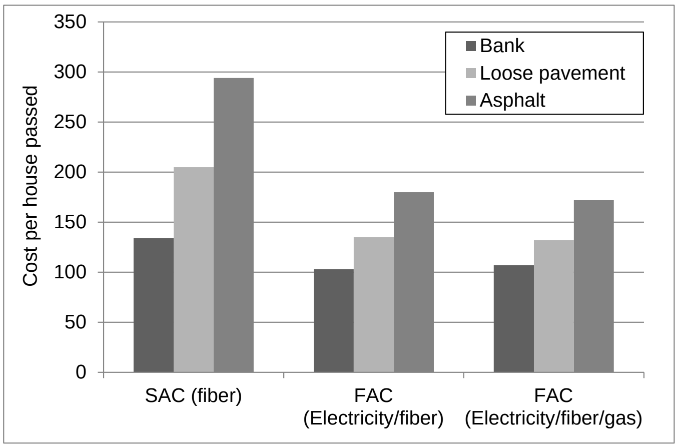


**Figure 9: Fiber cost reduction impact of pavement type**

## V. Conclusions and Future Work

In this paper we have shown that a joint rollout of infrastructure networks can have a positive impact on the total cost of a network rollout. Considering that over 60% to 70% of the total cost of a fiber network rollout is located in digging, already the smallest cost reduction has a major impact on the total investment cost. In this work we propose a joint infrastructure rollout to reduce this initial investment cost and speed up the rollout of fiber in the access network.

Rolling out several utility and telecom networks together has several advantages. It reduces the total time spent by contractors to roll out the networks. This results in reduced nuisance for inhabitants and small companies located in that area, who experience the most hindrance. A more important result of this reduced work time, more interesting for network operators, is the reduced cost. In the current model, only initial investment costs are taken into account. We have shown that in all scenarios cooperation has a cost reducing impact up to 17% per house passed.

However, we notice that currently utility and telecom operators do not always cooperate during the rollout phase of the network, especially in brownfield scenarios. New cables and ducts are only installed when necessary. This raises questions on the effectiveness of the cost reduction incentive. Should new regulation or penalty schemes be put in place to force cooperation between network operators to work together?

Future work will focus on synergy gains in operational costs, to drive down the costs even more. Also, the impact of cooperation on the common costs and coordination costs, like permits and taxes should be further investigated. The current model only calculates the cost reduction for the rollout of a standard trench in one street. In reality, the networks will be installed in larger geographic areas. The assumption that the standard trench will be installed everywhere will not hold. Crossroads, existing ducts and the need to cross streets will impact the dimensioning of the installed trench. All these challenges will be investigated furthermore in the TERRAIN project (Techno-economic research for future access infrastructure networks).

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